Creating Equitable STEM Access: Models of moving from theory to practice

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Abstract

My 3-paper dissertation is an extension of my own teaching experience. I became an elementary science specialist around the time that the Next Generation Science Standards (NGSS Lead States, 2013) were being created and a noticeable shift in science teacher literature and research occurred because of the inclusion of engineering and the push toward integrated science, technology, engineering, and mathematics (STEM) (Koehler, Binns, & Bloom, 2015; Roehrig, Johnson, Moore, &Bryan, 2015). While STEM education continues to receive funding and endorsements from government sources (Herschbach, 2011), the impact in K-12 schools remains limited. Atkinson and Mayo (2010) press that the issue around STEM education then is not “a lack of political will in Washington and state capitals, but a lack of the right approach to the problem” (p. 7). The three papers that comprise my dissertation explore approaches that are based on praxis between the existing literature surrounding STEM education and the practice of STEM. Like Atkinson and Mayo (2010), I believe that we need to reimagine our approach on integrating STEM in K-12 spaces, focusing on pressing realities that teachers work within each day. Each of the three papers that make up my dissertation address this issue in from a unique approach.

Paper 1, titled *Using Models of Integrated Curriculum to Describe Enacted STEM Learning when Prescribed Standardized Curricula was Present,* addresses the challenge of prescribed standardized curriculum when implementing new integrated approaches to teaching and learning. Standardized curriculum is a rising trend in public education, but this study also found it to be a barrier to STEM integration. In this paper, models of

integration that teachers used to integrate STEM when under the restriction of using a prescribed standardized curriculum are identified and described.

Paper 2, titled *A Teacher and Researcher's Reflection on the Aspects of an Effective School-University Partnership*, is based in a university-school partnership created to promote integrated STEM programming in urban middle schools. This study investigated how school-university partnerships can be an effective vehicle for STEM integration in schools. This paper details the working relationship and how an effective STEM partnership was implemented through co-created narrative inquiry from the lens of both the researcher and teacher leader. It also gives recommendations for those who are entering into partnership spaces in the future.

Paper 3, titled *What do Elementary Teachers need to integrate STEM?* was an exploratory study to determine what factors elementary teachers in schools with STEM programming identified as being important to STEM integration. A statewide survey was sent out to self-identified schools STEM schools that asked elementary teachers to identify what factors they believed were important to integrate STEM. As elementary teachers are not well-prepared to teach STEM (Goodnough, Pelch, & Stordy, 2014), it is important to understand their experiences and needs when asked to develop and promote STEM learning experiences for students. As an exploratory study, this paper provides suggestions and questions for those interested in STEM integration in elementary grades.

After looking at three studies of STEM moving from theory to practice, similarities across all three papers are identified and expanded upon. The last chapter summarized and expanded upon common themes across all three papers.

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Chapter 1: Framing the Problem

As a K-12 student myself I thought that I never enjoyed science, however, after reflecting on my own experiences it was not the science content, but the science pedagogy that discouraged me from believing that I could be a successful person in science. It was not until college that I experienced an inquiry approach (Bybee & Goodrum, 1999) in science spaces. This was a sharp contrast from the rote memorization I had come to believe was foundational in science courses. As I started my teaching career, I was determined to teach in ways that were reflective of my college experience, using inquiry and hands on experiences to guide learning.

I became an elementary science specialist around the time that both the Minnesota State Science Standards (2009) and the Next Generation Science Standards (NGSS Lead States, 2013) were being created and a noticeable shift in science teacher literature and research occurred because of the inclusion of engineering and the push toward integrated science, technology, engineering, and mathematics (STEM) education (Koehler, Binns, & Bloom, 2015; Roehrig, Johnson, Moore, &Bryan, 2015). This influenced me to not only integrate engineering into my elementary science classes, but to begin transforming it into a STEM learning space.

While there is not one agreed upon model of STEM education (Bybee, 2013) many researchers share a similar purpose of STEM education that goes back to its roots in the National Science Foundation (NSF): students need to become citizens that can solve the real-world problems of tomorrow (Kuenzi, 2008). When STEM appeared in the National Science Foundation (NSF), NSF had used STEM simply to refer to the four separate and distinct fields we know as science, technology, engineering, and/or mathematics (Sanders, 2009). In 2009, integrative STEM was defined as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (Sanders, 2009, p. 21). It is both the content knowledge from the individual science, technology, engineering, and mathematics fields, as well as the interdisciplinary approach that has made STEM education a valuable part of K-12 education (Zollman, 2012). Interdisciplinary STEM has other cited components as well. Kelley and Knowles (2016) argue that when learning is grounded "within a situated context, learning is authentic and relevant, therefore representative of an experience found in actual STEM practice" (p.4). Students should be learning content in a contextualized way that is relevant to how it is used in the real world. Similarly, Moore, Stohlmann, Wang, Tank, Glancy, & Roehrig (2014) state that STEM education should be "based on connections between the subjects and real-world problems" (p. 39). In contrast traditional science and mathematics teaching is often devoid of context for students, for example, Harris and Zwiep (2013) discuss how mathematics in particular is rarely situated in real life settings and includes data sets that have no meaning. STEM education is an opportunity to deviate from irrelevance creating opportunities for learning that are more engaging and meaningful to students. For the purpose of this dissertation, STEM and STEM education refer to the interdisciplinary STEM approach to learning.

As a new teacher, I was excited and encouraged by my students' enthusiasm for learning through integrated STEM approaches. However, it was also evident that most elementary programs did not emphasize engaging and authentic science and the time devoted to science in elementary school classrooms remained minimal. I was very discouraged by the inequity I saw; very few elementary students had access to science, let alone STEM education, in the state of Minnesota. I entered graduate school hoping to better understand why STEM, a promising research-based practice, seemed to be stuck in theory and research spaces instead of classrooms.

As someone who self identifies as a teacher-researcher (Lytle & Cochran-Smith, 1992), I knew that I wanted my dissertation to be pragmatic in hopes that it could be a resource for those beyond academia such as teachers, administrators, and policy makers.. While situating myself in academia, I was critical of the STEM publications that seemed to leave out the realities I had seen as a teacher having to navigate the impact of standardization of curriculum (Rivera, 2010), limited resources, and limited STEM professional development opportunities (Banilower et al., 2013).

While STEM education continues to receive funding and endorsements from government sources (Herschbach, 2011), the impact in K-12 schools remains limited. The report *Refueling the U.S. Innovation Economy: Fresh Approaches to Science, Technology, Engineering and Mathematics (STEM) Education* (Atkinson & Mayo, 2010), describes multiple pieces of legislation passed to support STEM over the years, but only 17% of 12th graders are both proficient in STEM subjects and interested in STEM careers (Khazan, 2012). On average, the U.S. government designates $3 billion every year into STEM education initiatives, more per pupil than other countries spend (Pittinsky & Diamante, 2015), yet, the average scores for American 15-year-olds in 2012 on the

Organization for Economic Cooperation and Development's Program for International Student Assessment math test were below the average of the 34 participating countries (OECD, 2013). Large gaps also appear in the demographics of those who are a part of the STEM workforce and those who are not. Women and those of Black, Native American and Hispanic descent continue to be underrepresented in STEM fields (National Science Foundation, 2013). Nationally, women make up only 19% of all undergraduates who enroll in engineering programs and Black, Hispanic, and Native American students make up only 16% of the enrolled students (National Science Foundation, Division of Science Resources Statistics, 2014). According to national employment data, women make up 15% of the engineering workforce and Black, Hispanic, and Native Americans make up only 11% of the engineering workforce (National Science Foundation, 2013). Atkinson and Mayo (2010) press that the issue around STEM education then is not "a lack of political will in Washington and state capitals, but a lack of the right approach to the problem" (p. 7).

The title of this dissertation, *Creating Equitable STEM Access: models of moving from theory to practice,* addresses the gap that exists between STEM funding and academic publications and the implementation of STEM in classrooms.

The three papers that comprise my dissertation explore approaches that are based on praxis between the existing literature on STEM education and the practice of STEM. Like Atkinson and Mayo (2010), I believe that we need to reimagine our approach on integrating STEM in K-12 spaces, focusing on pressing realities that teachers work within each day. Each of the three papers that make up my dissertation address this issue.

Chapter 2, titled *Using Models of Integrated Curriculum to Describe Enacted STEM Learning when Prescribed Standardized Curricula was Present*, addresses the challenge of prescribed standardized curriculum when implementing new integrated approaches to teaching and learning. Standardized curriculum is a rising trend in public education, but this study also found it to be a barrier to STEM integration. In this paper, models of integration that teachers used to integrate STEM when under the restriction of using a prescribed standardized curriculum are identified and described.

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Chapter 4, titled *What do Elementary Teachers need to integrate STEM?,* was an exploratory study to determine what factors elementary teachers in schools with STEM programming identified as being important to STEM integration. A statewide survey was sent out to self-identified STEM schools that asked elementary teachers to identify what factors they believed were important to integrate STEM. As elementary teachers are not well-prepared to teach STEM (Goodnough, Pelch, & Stordy, 2014), it is important to understand their experiences and needs when they are asked to develop and promote

STEM learning experiences for students. As an exploratory study, this paper provides suggestions and questions for those interested in STEM integration in elementary schools.

Chapter 5 is titled *Moving Forward*. After looking at three studies of STEM education moving from theory to practice, similarities across all three papers are identified and expanded upon. The question “how to integrate STEM?” is not simple and cannot be answered in a single study. This chapter summarizes common themes across all three papers, as well as providing suggestions for how to move STEM from theory to practice.

Chapter 2: Using Models of Integrated Curriculum to Describe Enacted STEM Learning when Prescribed Standardized Curricula was Present

Since a Nation at Risk was published in 1983 the discourse around education in the United States has continued to shift towards the creation of standardized curriculum (Burke, 2008). Prescribed Standardized Curriculum (PSC), according to the US Department of State, is “a set curriculum determined by the school or other authorizing body (Powell, 2004, section 4.6). While PSC has been cited as beneficial to highly mobile student populations and beginning teachers (Smagorinsky, Lakly, & Johnson, 2002), it has also hindered teacher autonomy (Bauml, 2016). Although they have always been guided by standards, teachers have expressed concern that standardized curriculum continues to decreases the autonomy they have in their classroom (Smagorinsky, Lakly, & Johnson, 2002).

While teachers in this study wanted to bring STEM (Science, Technology, Engineering, Mathematics) into their classrooms, they had to navigate how to integrate STEM learning into their PSC they were required to follow. The number of school districts that are using PSC continues to grow (Bauml, 2016) and finding meaningful ways to teach STEM in the classroom is becoming increasingly important under this constriction. While STEM education continues to receive funding and endorsements from government sources (Herschbach, 2011) it is still relatively absent in classrooms in part because teachers prioritize academic content that is linked to standardized testing (Schoen and Fusarelli, 2008). Many models of curriculum integration exist (Fogarty, 2009; Kysilka, 1998; Drake 1993; Jacobs, 1989) and in order for teachers to use STEM curriculum they must navigate what model of integration works best for them. Thus, guided by Kysilka's framework on curriculum integration (Kysilka, 1998), the research question for this study was:

> In instances where prescribed standardized curricula and STEM initiatives coexisted, what models of integration did teachers report using?

Prescribed Standardized Curriculum

The primary reason for the creation of prescribed standardized curriculum was concern about the "lack of uniformity of what was taught among secondary schools and concern about the lack of accountability of America's lower performing public schools" (Smagorinsky, Lakly, & Johnson, 2002, p.198). Along with standard content, these prescribed curricula came with a scope and sequence that suggested when and how each unit should be taught throughout the year. By creating district wide curricula to be used by all teachers, it was assumed all students would be offered the same high academic expectations and content. However, Garan (2002) argued that PSC take away from teacher autonomy in the classroom and eliminates their ability to create exciting and innovative learning experiences for their students. In essence, this deprofessionalizes the field of teaching, as prescribed curricula have taken the responsibility and control away from teachers and placed it into the hands of district, state, and federal mandate. Thus, proponents of public STEM schools are faced with the challenges of navigating between using research-based STEM practices and mandated prescribed standardized curriculum.

STEM Education

The term "STEM", originally "SMET", was first seen in grant proposals for the National Science Foundation (Johnson, 2012). Part of the STEM "frenzy" is the numerous grants and funding available for STEM related initiatives from the US

Department of Education and other federal and state agencies (Herschbach, 2011) in response to concerns about the lack of a qualified STEM workforce to fill the increasing number of STEM jobs. STEM employment opportunities are projected to grow faster than the average for all occupations between 2012 and 2022 (Vilorio, 2014) and implementing STEM education into schools is one way to prepare students to be successful in these future careers.

Additional arguments for STEM include the National Science and Technology Council (2013) who state that even jobs that are not in STEM fields will need the critical thinking and problem-solving skills that STEM education provides. It is also the case that the challenges that we are facing now and, in the future, such as climate change and clean water, are multifaceted and need an understanding of how many disciplines can work together to solve problems (Boggs, 2013). Thus, as educational practitioners we acknowledge that STEM careers should not be the only end goal of STEM education. The majority of students in K-12 classrooms will not become professional scientists or engineers. But all students need to develop 21st Century skills. These skills include problem solving, communication, and collaboration, and develop STEM literacy so they can read nutrition and medication labels and engage in civic debate such as when their state considers hydraulic fracturing or offshore drilling (Boggs, 2013). STEM literacy may help solve real-world problems such as environmental concerns, sustainability, health issues, energy, communication, and national security (Tanenbaum, 2016).

There are many models of STEM (Bybee, 2013) and no one model has been agreed upon as the “correct” model. However, the literature suggests different approaches that are associated with STEM education such as a teaching method that encourages active learning and student participation (Breiner, Harkness, Johnson, & Koehler, 2012; English, 2016; Labov, Reid & Yamamoto, 2010; Sander, 2009), putting together two or more of the content areas (science, technology, engineering and mathematics) (Breiner, Harkness, Johnson, & Koehler, 2012, Honey, Pearson, and Schweingruber, 2014, Kelley and Knowles, 2016; Moore et al., 2014) and presenting integration as a way to solve real world problems (Breiner, Harkness, Johnson, & Koehler, 2012; Brown, Brown, Reardon, and Merrill, 2011; English, 2016). Despite these variations, there are common elements, including: the inclusion of an engaging, real-world context (Breiner, Harkness, Johnson, & Koehler, 2012; Brown, Brown, Reardon, and Merrill, 2011), explicit connections between science, technology, engineering, and mathematics and modeling them as they would be used in STEM careers (English, 2016; Hershbach, 2011; Honey, Pearson, and Schweingruber, 2014; Kelley and Knowles, 2016), the intentional development of 21st century competencies (Authors, 2015; Honey, Pearson, and Schweingruber, 2014) and an emphasis on student-centered pedagogies (Breiner, Harkness, Johnson, & Koehler, 2012; Labov, Reid & Yamamoto, 2010; Sander, 2009).

Integrated Curriculum Models

Integrated curriculum came to light in the 1920's when John Dewey proposed integrated approaches to learning (Dewey, 1916). Since then, supporters have cited the benefits of integrated curriculum such as increased engagement (Lewis & Shaha). However, "integrated" is still an ill-defined term and multiple models of integrated curriculum exist (Drake, 1993; Fogarty, 1991; Jacobs, 1989; Kysilka, 1998). Although variations exist between models, each one relies on a continuum of integration. In each model, movement up and down the continuum is dependent upon what role the disciplines (subject matters) play in the organization of the curriculum, what role processes play in thinking about the curriculum, and what role the teachers and learners play in developing and carrying out the curriculum (Kysilka, 1998).

Kysilka's model was chosen for this study because it encapsulates the main ideas from other models that came before it and is representative of the continuum of integration that exists across the other models. Kysilka's model (Table 2.1) begins with separate disciplines on one end of the continuum moving to fully integrated at the other end. Unlike other models, Kysilka provides a richer description about the role of content, the allocation of time, and the responsibilities of both the teacher and learner for each stage of the model. First, separate disciplines is the traditional model of learning where classrooms are siloed and content is taught in a subject specific way. Teachers are not trying to make connections across subject areas and real-world contexts. Next is discipline-based learning which, like separate disciplines, is still content dependent and content specific. However, the teacher may change the sequence of their lessons so they are able to make outside connections or set time aside for practical applications. After this comes the interdisciplinary model which no longer relies on individual disciplines, but a "set of skills, themes, concepts, ideas and applications of content that is deemed important" (Kysilka, 1998, pg. 205). In the interdisciplinary model, time periods are flexible and teachers' pair or team up to plan and/or implement instruction rather than do it separately or on their own. The last model is total integration. In this model, the boundaries between disciplines disappear and classes are not constricted by time requirements. Students choose a topic to study based on personal relevance and interest. Students and teachers work together to establish strategies for the exploration. The teacher is responsible for facilitation of learning, not direct instruction.

Table 2.1

Kysilka's model of Curriculum Integration (Kysilka, 1998).

	Separate disciplines	*Disciplined-based*	*Interdisciplinary*	*Total integration*
Content	Separate subjects	Sequenced Correlated ideas Focused content themes Multiple lenses Modified courses	Multifaceted lens Broad themes Process themes Student interests New courses	Student needs/interests Cross disciplines Integrated day Apprenticeships Experiences
Time	Distinct units/periods	Distinct units/periods	Blocked	Varied
Teachers	Separate	Separate	Paired/teamed	Teamed/facilitators
Students	Receivers	Receivers/doers	Doers/decision-makers Creators	Decision-makers Creators Independent investigators

Methods

This study implemented a qualitative research design (Miles, Huberman, & Saldaña, 2014). STEM teams were comprised of teachers and a graduate STEM researcher who also acted as a coach. While each STEM team was working toward the same goal of developing STEM programming, their process, as well as implementation, looked different across STEM teams and school sites. This methodology allowed for comparisons of differences and similarities across STEM teams as they developed STEM programming under the restriction of prescribed standardized curriculum.

Context

Teachers from four STEM middle schools and one 9th grade STEM academy in a large urban Midwest district participated in a year-long STEM development program with a large public university in the Midwest. All of the schools qualified for Title I funding and served diverse student bodies. The overarching goal of the project was to research how schools develop STEM programming through STEM teacher leadership teams. Teacher leaders were chosen based on previous STEM training or an interest in STEM education. The lead teachers, in collaboration with school and district administrators, developed a STEM team comprised of teachers who self-selected or appointed to be on the team for the year.

No formal definition of STEM was provided to the teams; instead they were tasked to define what STEM meant at their school. The research team recognized that STEM implementation would look different at each school site and so no specific protocols or models were required of the teachers, however, the STEM School Critical Components were given to the teams as a guide to use to inform the schools' STEM implementation. Teachers were offered professional development opportunities, a STEM Fellow from the University with STEM education expertise, and financial support during the school year to help with the transition process and create integrated STEM opportunities during the school year. The professional development that was offered consisted of multiple day long sessions scheduled throughout the year. An expert guest speaker on STEM schools was brought in to help teams set their own school goals. Professional development attendance was mandatory and teachers were paid for their time. The STEM Fellows were graduate students with prior K-12 STEM teaching experiences. They worked alongside the teacher teams and attended all of the team meetings and professional development opportunities. STEM Fellows observed, and in some cases, co-taught in the classes as well. The STEM Fellows were responsible for recording the team's meetings and actions, and also to seek out resources for their STEM implementation such as existing curriculum and material resources.

All of the teachers were under the restriction of using the district's mandated prescribed standardized curriculum. The adopted standardized curriculum included a scope and sequence for the year, which meant that teachers were supposed to follow a map for what content was supposed to be taught and when it was supposed to be taught. The curriculum included lesson plans and assessments that the teachers were supposed to utilize. While there was some flexibility with teachers on using the existing lesson plans, all of the teachers had to report the assessment grades to their administration. While each STEM team took up the task of creating integrated curriculum differently, they all faced the common obstacle of prescribed curriculum while trying to integrate STEM.

Participants

Twenty-four participants were chosen from four school STEM teams using purposeful sampling (Suri, 2011) based on the STEM team's completion of at least one STEM unit throughout the school year. Four out of the five schools that participated in the STEM development program are represented in this study; one school only implemented a Family STEM night and did not implement an integrated unit during the formal school day.

Data Collection

Data sources were collected throughout the academic year in the form of researcher memos and teacher interviews.

Researcher Memos. Each school was assigned a STEM Fellow as a part of the University partnership. Researchers were asked to memo bi-weekly about the actions taken by the STEM team at their school site including STEM projects, team meetings, and any information regarding the process of developing or teaching STEM curricula. The memos included those in attendance, what the team perceived as being successful, what they perceived as being challenging, goals that the team set and resources that were required. These memos served as the primary source of data providing information about STEM implementations and challenges throughout the academic year.

Teacher Interviews. Two rounds of interviews were conducted during the academic year. Each teacher was asked to participate in one pre-interview in September and a post-interview in May. All interviews contained questions regarding the teacher's definition of STEM, STEM projects that they had participated in and limitations and affordances that came up while trying to integrate STEM in their classrooms. The STEM Fellows transcribed the interview data sources that were used as a secondary data source to elaborate on reasons for the STEM activity described in the researcher memos.

Data Analysis

Using Kysilka's model of integration, codes were established to describe integrated curriculum. These four codes were "separate disciplines", "discipline-based"," interdisciplinary", and "total integration". The data sources were deductively coded

(Miles and Huberman, 2002) and the STEM units were categorized into one Kysilka's four models. Then, using both the researcher memos and the teacher interviews, descriptive cases of the STEM teams were written. These descriptions detail how the teachers were able to integrate STEM in the presence of a prescribed curriculum.

Results

Discipline-Based Model

Joliet Middle School. The 6^{th} grade STEM team at Joliet Middle School was comprised of the science teacher, English teacher, mathematics teacher and the assistant principal (see Table 2.2). Although excited about STEM, each of the teachers voiced concern about participating in too many initiatives beyond the class they taught. Ms. Breech ran the 1:1 technology program and Ms. Maher headed the committee that was responsible for responsive classroom training and implementation at the school. Mr. Croth was also concerned about a new literacy block, and that STEM team would not receive the support they needed to integrate STEM into their classrooms when resources were being allocated to literacy. Fitting with the model of discipline-based, Mr. Croth shared that his school was,

> "not close to a STEM school, the classes are still siloed, demands are too great on the teachers to make it what you want it to be. This year the school day was extended by an hour to add an extra literacy hour that all teachers teach so they have been busy creating what [the literacy block] looks like in their classes."

Table 2.2

Joliet Middle School STEM TEAM

Teacher	Grade/Content
Ms. Amber	Assistant Principal
Ms. Maher	6^{th} grade ELA
Ms. Breech	6^{th} grade Science
Mr. Croth	6^{th} grade Mathematics

After three STEM team meetings, Mr. Croth decided that the STEM team was not going to have time to use an interdisciplinary model to integrate STEM across content areas within the semester. He acknowledged "we need more cross communication between subject matter, teachers don't look at each other's targets or benchmarks." Because of the barriers he referenced, he decided to try a STEM unit in his math classroom. Mr. Croth asked the university STEM Fellow to work with him to find a STEM unit that would fit his upcoming PSC math unit. They had a planning meeting where they looked over the PSC objectives, lessons, and assessments. After doing so, they brainstormed possible science and engineering activities, as well as technologies that could be incorporated into the math lesson. They decided to use a three-day lesson around erosion and surface area that the STEM Fellow was familiar with. Students would use erosion trays to model fast and slow earth processes, and then propose a new building site for a school. Students individually built models of the school that accurately represented the amount of safe building space available.

Mr. Croth often mentioned that STEM required financial resources and teacher time. Although he was working in a disciplined based model, where traditionally the teacher would work alone, the university partnership was able to provide him with support because of his participation on the STEM team. After the unit was over Mr. Croth reflected that we would like to have more STEM integration opportunities because he saw the student engagement, but that the administration would have to prioritize STEM if they wanted to try a model of STEM integration beyond single disciplines.

The other teachers on the STEM team did not implement an integrated STEM lesson, however, as a STEM team they put on a STEM night for students and families. At this event, students built mousetrap cars and competed against each other. The other two teachers struggled to find time within the school day to replace their PSC, so an afterschool event was their alternative option.

Noddack Middle School. The STEM team at Noddack included five teachers who taught in 6^{th}, 7^{th}, and 8^{th} grade classes (see Table 2.3). One of the team's greatest challenges was finding a common time to meet because they taught in different grade levels and their schedules did not allow for common planning during the school day. The team met once a month on Friday afternoons which their team lead Mr. Rush acknowledged was "not ideal". At one of the team meetings, the 6^{th} grade team realized that in order to create an integrated unit they would have to align their PSC, and that meeting once a month would not allow for a project of that size. Instead, teachers decided to try an integrate STEM into their classrooms individually. Each of the team members established goals to integrate STEM, however Mr. Rush was the only one who implemented an entire STEM unit.

Table 2.3

Noddack Middle School STEM Team

Teacher	Grade/Content
Mr. Ahmed	8^{th} grade Social Studies
Ms. Nyberg	6^{th} grade ELA
Mr. Rush	6^{th} grade Science
Ms. Mark	6^{th} grade Mathematics
Mr. Lee	6^{th}-8^{th} grade ELA

Mr. Rush recognized the benefits of PSC, but also that it constrained the team when trying to work together to integrate STEM. Mr. Rush shared

> "Our district is standardized curriculum, so there's a designated guideline for lessons and benchmark units. We have a highly mobile population, so the idea is that if kids move from school to school, they're kind of on the same flow. Like all 6^{th} grade classes in the district should be teaching the same thing… that kind of confines us a little".

Mr. Rush did not want to use the discipline-based model of STEM integration, but the PSC along with a lack of common planning time and other school initiatives did not support interdisciplinary models of STEM integration. The principal at Noddack supported STEM, but made it clear that they were not going to become a STEM school, they were an International Baccalaureate (IB) school. Ms. Mark commented that the IB program was conducive to STEM because of its interdisciplinary approach, however grade level teachers were not given common planning time to really maximize the potential of IB or STEM curriculum.

In spite of constraints within the school system, Mr. Rush still wanted his students to experience STEM, so he looked at his PSC units and found places to "STEMify" the lessons that were given to him. For example, when he was teaching about light, instead of using the PSC, he wrote his own STEM curriculum about a laser maze security system. His students were still learning the required benchmarks, but Mr. Rush supplemented the science activities with an engineering challenge. In the unit, the students were tasked to build a laser security maze for a traveling museum. The students designed the museum by choosing artifacts and placing them within a 2-foot by 2-foot square which was the pre-determined size of the model museum. Then, they were given a single laser, prisms, and mirrors to create their security system. After building, they tested their security system by checking to see if an intruder could get inside the museum and to an artifact without walking through a laser beam.

The Noddack STEM team was vocal about the impact PSC had on their teaching, particularly Mr. Rush. He believed that because he was a science teacher, it made it easier for him to integrate STEM into his PSC than for the ELA or social studies teachers. During a team meeting, Mr. Ahmed also commented that the engineering components in science supported STEM more than any social studies standards. He said "social studies especially seems to be very focused on content-level standards, rather than in skill or deeper thinking type standards, they seem to kind of have a list of things I'm supposed to teach about, or at least it feels that way because there's just so many of them". Mr.

Ahmed's comment identified the struggle teachers who did not teach a STEM content felt during the STEM development program.

Interdisciplinary Model

Noether High School. The Noether STEM team consisted of all of the 9th grade teachers, six in total, the assistant principal and the STEM coordinator (see Table 2.4). Noether High School had been reopened as a STEM academy and the administration was very active in STEM integration development. The assistant principal was hired because she had a strong background in STEM education. The administration supported the STEM team as the vehicle to move STEM integration forward in their school. Because of their STEM focus, the administration wanted all of the grade level teachers on the team.

Table 2.4

Noether High School STEM team

Teacher	Grade/Content
Ms. Norwork	Assistant Principal
Ms Laughlin	STEM Coordinator
Ms. Malil	9th grade ELA
Mr. Case	9th grade Science
Mr. Drake	9th grade Mathematics
Ms. Amy	9th grade Social Studies

Teachers at Noddack were given time by the administration to collaboratively combine their PSCs with a STEM unit. They began by looking at ways to connect upcoming units across disciplines and chose the theme of "revolutions" to write a STEM unit using existing benchmarks from the PSC. Ms. Malil described

> "when I did [the Revolutions unit], we were talking about inertia [in science] so we were trying to create a social movement in social studies. Some kind of status quo and how do we change the status quo through movement...and the kids were into it, the teachers were into it".

Mr. Case addressed science standards around force and motion. Mr. Drake tied into the theme of revolutions by comparing home ownership statistics in the community by racial demographics. In Ms. Malil's class, students read a novel that depicted racial injustice that informed students as they discussed social movements. The novel was not the one recommended in the PSC, so the school purchased the novel chosen by the teachers.

Although the teachers were still confined to their classroom periods, the Noether team falls into the interdisciplinary model. The revolutions unit was written around social injustices happening in their community surrounding the school and asked the students to use their knowledge across subject areas to create an action plan. Although explicitly addressed in social studies and English, all of the teachers tied into the theme in their content specific classrooms. According to Kysilka's model, this move from teacher centered to student centered instruction may have been possible because the teachers viewed the standardized curriculum as a framework more than prescribed content to be taught. Ms. Case explained,

> "the standardized curriculum was just a framework, and therefore teachers only want to work within the frameworks because this is what you told me to do and that's what I'm going to do because I know you're going to hold me accountable on that…

Similarly, Ms. Malil acknowledged that the standardized benchmark assessments were what the students would be held accountable for learning, but they did not need to use the related lessons. Because of the administrative support to integrate STEM, she felt that her team could create new lessons that would teach the same content benchmarks.

Falconer Middle School (Sixth grade team). Falconer had been re-opened the previous year as a STEM school. Instead of creating one large inter-grade level STEM team, each grade level formed their own STEM team. The 6th grade team was made up of three teachers and the STEM coordinator (Table 2.4). While an administrator was not on the team, the principal did provide a weekly STEM team meeting time as a part of the teachers' contract work day. Falconer had offered teachers different summer professional development opportunities to support the school's STEM focus. When deciding on what they wanted to teach for their integrated STEM unit, Mr. Loa suggested Medical Detective, a Project Lead the Way unit, because he had attended the training and felt that although the curriculum was based around science standards, it could provide entrances to multiple subject areas.

Table 2.5

Falconer Middle School 6th Grade STEM Team

Teacher	Grade/Content
Ms. Biel	STEM Coordinator
Ms. Appel	6th grade ELA
Ms. Lovan	6th grade Science
Mr. Mayor	6th grade Social Studies

During Medical Detectives, students worked to solve a murder mystery using scientific processes such as DNA Electrophoresis and performing a mock autopsy report. During their team meetings, each teacher looked through their PSC units and found lessons with standards they could align to Medical Detectives and moved their other PSC units around to make this interdisciplinary model work. In science, students learned about genetics and DNA, while in social studies students looked at crime rates in their surrounding community. In social studies they researched the history of medical detective schools and in English they used their knowledge from the other three classes to write a persuasive argument around a legal case as to whether they thought the defendant was guilty or not. The teachers used their weekly STEM meeting to create a rubric that addressed what each teacher would be doing during the unit, as well as when they would teach the lessons, so students were experiencing a coherent interdisciplinary model. Mr. Loa reflected that he was willing to rethink the order of units because he was "willing to dedicate [himself] towards the success of students" and he believed STEM was a pedagogy that his students were engaging more in then when they taught PSC in siloed classrooms. He also acknowledged

> "we have teachers who are willing to do the work. The only problem with that is they're not necessarily trained in a science or in STEM in school to do the work. And that's not their fault. I'm not gonna say whose fault it is but what they have to be structural and there's no protocol and structure a school wide reflect".

Mr. Loa summarized that as a school, there was not a set model of STEM given, so the STEM teams were left to decide how they wanted to implement STEM among their team.

Mr. Loa's reflection of the process suggests that he felt some structure was lacking, either professional development for the team or a protocol for STEM integration. Even so, their team was able to come up with an integrated model that worked in their siloed classrooms.

Total Integration

Falconer Middle School (Eighth grade team). The Falconer 8th grade STEM team consisted of four teachers and the STEM coordinator (Table 2.5). The 8th grade team met once a week during the school day during a common planning period. The administration supported teachers in using this time to work towards STEM integration. The STEM team was tasked to create at least one integrated stem unit together, however, the team decided to wait until after standardized testing was completed in the spring so the team did not have to worry about how to incorporate their PSC units. The timing allowed the teachers to bring all of the 8th grade students together in the lunchroom for an entire day and not be constricted by class scheduling.

Table 2.5

Falconer 8th Grade STEM Team

Teacher	Grade/Content
Ms. Mohamed	6th-8th grade Art
Ms. Biel	STEM Coordinator
Ms. Vonage	8th grade Science
Mr. Harper	8th grade Social Studies
Ms. Coring	8th grade ELA

The park next to the school was being rebuilt and Ms. Mohamed, a local artist in the community as well as the art teacher, was asked to be on the planning committee. As a part of the process, the committee was getting input from the community and local schools. Ms. Mohamed suggested during a meeting that they use the park rebuild as the context for the 8th grade interdisciplinary STEM unit. The team agreed and wrote lessons and specifically identified where students would be engaging in science, technology, engineering and mathematics.

The planning committee members, designers and architects came to speak to the students and identified the need for models of a new park that represented what the community wanted. After hearing about the park project, students worked in groups to design surveys and interview classmates and community members about what they would like to have in a neighborhood park. After gathering data, the groups continued to design and build models to present to each other and the planning committee. The teachers acted as facilitators and did not stick to the liseced areas they traditionally were assigned. For example, all of the teachers were assisting in mathematical measurements and graphing.

The 8th grade Falconer STEM team unit fit Kyslika's model of total integration based on their ability to change the schedule to accommodate integrated learning, focus on students taking an active role in their own learning, and working across disciplines. At the beginning of the unit, Ms. Mohamed said.

> "you know, I'd be particularly interested in trying to find ways to glean from the students what they would be interested in seeing in this space or what would make this a more interesting space to them than simply a playground...it is really cool

> for [students] to see what does it really take to rebuild something, how many committees do you need. How many people do you need to reach out to? What about money marketing brochures and you know just the business aspect of it. And you know the science aspect in the water here".

The students were actively involved in their learning, but also actively involved in their community as the students' designs were used in the park.

Discussion

No one size fits all model

While each of these schools was working with the same project resources and the same PSC, they chose different models of implementation for their integrated STEM units. And even within a single school, different grade level teams chose to take on STEM integration in different ways. This study suggests that there is not one specific model of STEM integration that can be replicated from school to school and that the models identified in this paper are not comprehensive. When schools are looking to integrate STEM, the model that they decide on will be determined by the individuals and unique school culture that they embody.

Teachers experience different levels of autonomy

The amount of autonomy that teachers experienced at each school varied and consequently impacted the model of STEM integration that they chose. During the STEM team meetings at Noether, teachers and administration worked collaboratively towards creating integrated learning experiences for students. The assistant principal and the STEM coordinator also gave the teachers flexibility in the use of the district's PSC. The teachers still used the benchmarks as guides, but the math and social studies teachers wrote their own lessons. Although the 8th grade STEM team at Falconer was also given autonomy from the principal and designated meeting time, they felt they were not able to integrate STEM into their PSC and so they waited until they finished the PSC for the year and added STEM on after. While both STEM teams were given dedicated time towards STEM integration, the outcomes were realized in different ways. This may be because the two teams had different perceptions on how much autonomy they had in diverging from the PSC. Prescribed curricula take away from teacher autonomy in the classroom (Garan, 2002), but the extent of how much autonomy is taken away varied amongst the STEM teams. The administration at Noether was more explicit in telling teachers they had freedom in rearranging and editing the PSC to meet the STEM teams needs and this in turn led to their team working their integrated STEM unit during the school year instead of placing it at the end of the year when their PSC was completed.

Unlike Noether and Falconer, Noddack and Joliet teachers were not supported by the administration in collaborative time dedicated to STEM integration. In the interviews, the administrators were not against STEM integration, in fact they verbally supported it, but could not allot dedicated meeting time for STEM integration. Other school initiatives that were taking place were given higher priority, such as literacy, and those were the focus of meetings. Mr. Rush and Mr. Croth still experienced autonomy to integrate STEM, but they were limited to doing so within their own classrooms. They could not move any farther on Kysilka's model of integration without either supported meeting time or working on STEM integration on their own time without compensation for their work.

Across all four schools, the administration played a key role in the amount of perceived autonomy that teachers felt. None of the teachers believed that the administration was against moving towards STEM integration, but the amount of support they were given from the administration greatly impacted the model of interdisciplinary STEM the teams were able to achieve. STEM teams that were given verbal support from their administration, but no time to meet, were not able to move beyond STEM integration in a single class. The STEM team that was given time to meet, but not encouraged to change up the PSC was limited to implementation only when the PSC was completed. In this study, autonomy was founded on what the administration said as well as the actions it takes to support their verbal commitment. Autonomy in STEM integration is multifaceted and cannot be looked at singularly.

An Incomplete Model of Interdisciplinary Learning

Kysilka's model of interdisciplinary learning combined aspects of previous models and molded them together into a more comprehensive framework (Kysilka, 1998). As the STEM team units were deductively coded, we found that what the STEM teams had accomplished was not fully described by the Kysilka's framework. The students' roles were not presented in the model as they were enacted by the STEM teams.

According to Kysilka's model, only in the interdisciplinary model and total integration do students have an active role in their learning as decision makers, creators, and investigators. This study found that in all of the models, students were making decisions about their learning and had creative engagement opportunities. Mr. Croth and Mr. Rush used the disciplinary based model, but in both classes, students were engaging in an engineering challenge in which they were creating and investigating through engineering challenges. In both cases, students also spent time investigating the problem through physical manipulatives before identifying a solution. Kysilka's model also portrays students as passive or receivers in the discipline-based model, but this inaccurately represents the possibilities of quality STEM integration unit in a disciplinary classroom.

Kysilka's model also fails to acknowledge the approach to learning that is being enacted. The 8th grade STEM team at Falconer designed their STEM unit around the local park that was being redesigned. The teachers were drawing upon their students' lived experiences as a way to engage learners. Students were tasked to survey community members and then used the data when developing new designs for the park. This is very different than the Mr. Croth who used an existing STEM unit that had no connection to the student body as his school. In Kysilka's model there is no way to differentiate the type of pedagogy that teachers are choosing.

Conclusion

The number of schools, states, and countries that are using standardized curriculum is increasing (Priestley, 2011) and with standardization of testing and assessment tied to national reforms it will not be going away soon. However, while working under the constraint of a standardized curriculum may provide a challenge, teachers are still able to work in and around it to also teach STEM in their classrooms.

Teachers in this study, were able to implement Kysilka's models of integrated learning – disciplined-based, interdisciplinary, and total integration to provide integrated STEM experiences for students. However, we did find that Kysilka's model of integrated learning could not accurately depict the pedagogical approaches that the teachers were choosing to use. We argue that the rich learning experiences students engaged in need for Kysilka's model to be elaborated upon. However, as more educators and schools simultaneously are interested in STEM while adapting PSC, using an existing model can be useful in describing levels of integration, especially when speaking to administrators about the amount of autonomy teachers need in order to reach higher levels of interdisciplinary teaching.

Chapter 3: A Teacher and Researcher's Reflection on the Aspects of an Effective School-University Partnership

Traditionally in educational research, it is the researcher who is responsible for setting the research agenda and also for reporting findings that came from data collected (MacLean & Mohr, 1999). Because of the researcher's overarching influence, the teacher's voice is often muddled or left out altogether (MacLean & Mohr, 1999). One way to equalize the power differential between teacher and researcher is through school-university partnerships. In recent years, school–university partnerships have become one of the most prevalent strategies for educational change (Zelleramayer & Margolin, 2005). In this study, teachers and a researcher participated in a school-university partnership to develop STEM (Science, Math, Engineering, and Mathematics) curriculum as a part of a yearlong professional development. The teachers, as well as the researcher, had a common interest in bridging this divide between theory and practice surrounding STEM implementation.

This paper presents a portrayal of how a partnership was formed and the experiences of the members of a 6th grade STEM team while integrating STEM across multiple content areas and classrooms. In order for both the lead teacher and researcher to share their experiences of the same events through their different lenses and perspectives, narrative inquiry methodology was used. The term "co-researchers" is used to describe the collaborative efforts of the teacher and research in this paper. Through multiple iterations of constructing and analyzing vignettes, the research question we aimed to answer was:

How did a teacher and researcher sustain a school-university partnership?

School- University Partnerships

While much of the literature around school-university partnerships in the past 20 years has depicted a symbiotic relationship between participants (Dippo, 2005), which has not always been the case. Both Clark (1986, 1991) and Su (1990) did extensive reviews of school-university partnerships and found that they were far from being mutually beneficial relationships. As Goodlad stated “for 5 decades since World War II, the relationship between schools and universities has not been symbiotic” (1993, pg. 29). Johnson goes on to explain that during this time professors needed students and teachers for research in institutions that were increasingly demanding research productivity, but little of the research findings were communicated directly back to sites. Additionaly, forms and means of writing it up for publishing in journals made the results almost inaccessible to practitioners (1989). Maurrasse (2001) described this model as “university-as-landlord and consumer of locally produced goods” (pg. 54). Instead of the university and schools working together, the university’s goals and needs were prioritized because they embodied the power position. Researchers were taking what they needed for their own gains and the schools and students were not benefitting.

However, the past 20 years have seen an influx in conferences devoted to what it might mean for the university to be socially responsible to the K-12 schools that surround them (Dippo, 2005). The presence of school-university partnerships has been increasing in the educational literature because of the possibilities they present for enhancing equity and accessibility in education (Bourke & Jayman, 2011; Dippo, 2005). When schools and universities join together, they are able to accomplish something that neither are able to do on their own, creating potential for real reform (Pugatch & Johnson, 1995). When describing the role of teachers and academics in relationship to STEM partnerships, Bissaker (2014) said the academics learn "pedagogy from teachers and the teachers value the opportunity to learn about cutting edge science" (pg. 58). It is through interactions between teachers and researchers that something new can be collaboratively developed

The partnership model used in this study is Levin's (1993) school-university partnership model. He defines partnership as work "conducted by school educators and university researchers working as partners, with the goal of producing knowledge that is meaningful and useful for both educators' practice and for academic purposes" (pg. 331). We chose this model because we believed that collaborative research meant research should be done *with* the teacher instead of *on* the teacher which is too often the documented case in educational research. For this partnership model to be successful, mutual interests, shared goals, shared power and ownership of the research acted as key features of our collaboration from the onset of the project until the end. These characteristics guided our planning, implementation, and reflection process for this study.

Insider-Outsider Research Teams

Bartunek and Louis (1996) describe those who are insiders as people who are inside a setting being studied and outsiders as the researchers who are conducting the study. The idea of insider-outsider status is understood to mean "the degree to which a researcher is located either within or outside a group being researched, because of her or his common lived experience or status as a member of that group" (Gair, 2012). The status of insider-outsider is not fixed, but fluid (Haviland, Johnson, Orr, & Lienert, 2005). The separation of insider and outsider is in part due to differences in their purpose for gaining knowledge (Bartunek & Louis, 1996). Teachers are looking for "localized theories" that impact student outcomes and practice while researchers tend to form "generalized theories" that may or may not be useful to the setting where the data was collected and the generalized theory was formed (Bartunek and Louis, 1996, pg. 6) Instead of dueling agendas, it is suggested that the insider and outsider become co-inquirers and develop research questions together that meet both party's needs.

Power is also an issue at play between insiders and outsiders. In the past, outsiders have been the "controllers and possessors" of not just setting the research agenda, but of interpreting the situation through publication (Bartunek & Louis, 1996). Becker specifically addresses the need for a shift in power between outside researchers and inside group members. She challenged that this was no longer acceptable to "send a copy of one's book back [to the insiders]" once the research was done, but instead, the insiders need to be a part of the process both collecting, synthesizing, and publishing as well (1991, pg. 394). Bartunek and Louis agree with Becker that "inquiry into human systems needs to involve the human members of those systems as active participants in inquiry rather than merely as passive subjects" (1996, pg. 63). For this reason, it is suggested that insiders and outsiders "jointly examine the setting and jointly author public accounts of life in the setting" Bartunek & Louis, 1996, pg. 3). Insiders and outsiders may interpret the same situation differently. When only the outsider viewpoint is told, it limits the scope in what is reported. The ideal outcome is the "development of new perspective that goes beyond both the insiders' and outsiders' original viewpoints, such as a new way of understanding" (Bartunek & Louis, 1996, pg. 50).

Methods

Narrative Inquiry

The tools of narrative inquiry (Clandinin & Connelly, 1990; Taylor & Bogdan, 1984) were utilized to make sense of the experiences of the co-researchers in this study. As two people entering into the same experience but in two different roles, one as a teacher and one as a researcher, narrative inquiry, defined by Clandinin and Connelly as "the study of experience as story" (1990 p. 477) allowed for both voices to be equally heard; and thus co-researchers will be the term used to describe this partnership. In general, the interest on narratives has been motivated by the idea that individuals make sense of their 'realities' through the stories they tell and hear (Smith & Sparkes, 2006). Narrative inquiry can be utilized in understanding an experience (Clandinin, 2006) as it is able to represent the multilayered and nuanced nature of experience that cannot be demonstrated through other research representations.

Narrative inquiry encompasses a wide range of actions and products. As stated by Beaton (2014), "by using narrative, writing is simultaneously the process and product, data and analysis, findings, and representation" (p. 1034). Narrative inquiry typically takes on two shapes, narrative construction (Barone, 2007) and narrative analysis (Polkinghorne, 1995). The narrative relies on co-construction to help relay the experience of the partnership. Co-constructed narratives view relationships as "jointly authored" and they “illustrate how people collaboratively cope with the ambiguities, uncertainties, and contradictions” of partnership (Bartunek & Louis, 1996).

Narrative construction in this study followed Polkinghorne’s model that collaboratively collected “descriptions of events and happenings and synthesized or configured them by means of a plot into stories” (1995, p. 12). Narrative analysis then is “the process in which units of storied data are analyzed to find themes that hold across the stories” (Polkinghorne, 1995, p.12). Narrative analysis asks the researchers to examine the ways the story is told and “inspect the different stories to discover which notions appear across them...through inductive or deductive processes (Polkinghorne, 1995, p. 21). Each time a vignette was written, it was read over by both authors. The analysis of the vignettes brought deeper awareness of seemingly organic occurrences emphasizing pivotal moments. Many of the vignettes were re-written multiple times until they portrayed the experience accurately for both authors. Through iterations of vignettes, notions and common themes that occurred over time were identified and discussed in the findings of this paper.

Context

This study took place at a middle school in a large, urban, midwestern public school district. The school was part of a larger project supporting the development of urban STEM schools through the creation of STEM teams. Teachers at the schools self-selected to be a member of a STEM team, agreeing to work throughout the academic year to integrate STEM into their classrooms. The goal was to create at least one interdisciplinary STEM unit during the school year. For support, the team was assigned a

STEM fellow from the university to assist them with their work throughout the year. The university also provided funding for materials, as well as professional development around integrated STEM teaching and learning.

The co-researchers

Cory was a 6^{th} grade science teacher and he was in his 5^{th} year of teaching when this study took place. He had 4 years of STEM professional development and classroom experience and thus, was invited to participate as the teacher leader for the STEM team by the university based on his interest, experience and engagement with STEM.

Jamie, the university STEM fellow, had previously worked as an elementary science teacher for 5 years in the same district as Cory. She had transitioned from K-12 into higher education and was working as a STEM fellow on the STEM program development project. The co-researchers had attended several STEM workshops together and had established a working relationship before the project began. It was because of this relationship that Jamie was assigned to support the STEM teacher team at this school.

Compilation of the Vignettes:

Data was collected between August 2017 and June 2018. Sources of data included bi-weekly memoed STEM happenings at the school, transcribed team meetings, and the iterations of vignettes. As a part of the narrative writing process, both the Jamie and Cory reviewed the data sources that were collected throughout the school year to ensure accuracy of their accounts. The data was co-constructed into stories representing the experience of both the teacher and the researcher as they engaged in partnership. After each iteration, the co-researchers analyzed the experience and talked through the common themes that were occurring, discussing whether or not the vignette was a true depiction of the work and collaboration of the STEM team. The vignettes and the analysis are presented in the following section.

Vignettes

August: Establishing Roles

Cory walked into the STEM Center at the University for his meeting with Jamie. She wanted to talk to him about the upcoming STEM partnership. As Cory walked in to the building, a poster on the wall caught his attention. The poster had pictures of students working with lasers and prisms and as he looked closer, he realized the curriculum they were using had been written by his team of teachers as part of a different STEM project at the university. As a middle school teacher, he enjoyed the autonomy and resources that the university had provided his classroom. However, he had never really thought about where the information that was collected in his classroom went. He figured someone used it, but no one had ever followed up with him. For the first time, he was seeing what happened to the data collected in his classroom.

Cory: Oh my gosh, I think this poster has to do with me, isn't that the curriculum I helped write?

Jamie: Yeah, that is your curriculum, I believe that is Erin's work, she presented that at the last science teaching conference.

As Cory investigated closer, he began to realize that not only was the curriculum that he helped co-wrote represented, but a lot of the data that was displayed was from his science classroom and his 6th grade students.

Cory: Wow, I didn't even know all of this happened! I feel a bit disconnected from the research that was done.

Jamie: It's crazy right, I didn't realize how the information collected in our classrooms was used until I started working here.

This was a perfect time for Jamie to start a conversation about ideas for research and the project's goals for this to be a collaborative effort.

Jamie: This seems to be a common theme with the relationship between researchers and teachers, and my main goal is to make sure this doesn't happen. You know we will be working together this year and I want you to be a part of the research and I want to be more present in the classroom. I just left teaching so I feel like I can jump in where you need me and you have been on this project for two years, you should have more control of what the research focus is.

Jamie (pointing to the poster on the wall): You know there is funding for you, we can do that part of the work together.

Cory: I always want to help researchers, because I know the work is important, but when I see all of this, I realize that the results of all of the hard work wasn't even portrayed to me, or even a benefit to me. I makes me not want to agree to doing any more of this, if I don't benefit from any of it. No matter how you look at it, it is more work for me, and I am already working in one of the highest burnout rate *professions, especially at my setting, and to be asked to do more work, just to benefit someone else is a bit discouraging.*

Jamie: I asked to work with your team because the focus of my research is to make strong, positive, productive partnerships between the researcher and school. We both know how important university partnership has been to bring STEM into our own classrooms in the past, but I think we can do a better job connecting the teacher and researcher.

Cory (partly joking): You mean you won't silently write notes about me in the back of the room while I teach?

Jamie: Exactly, and that's why I wanted to meet before school starts, I think we should start planning this out together.

September: Choosing the STEM Team

After the meeting with Jamie, Cory decided to stay on with the STEM research project mainly because she assured him that he could pick the members of the STEM team and they could set their own agenda for STEM implementation throughout the year. In previous school teams, he found that productivity could be killed depending on who was in the group and the lack of leadership at the school allowed this to happen so often that it was very normal to have hour-long meetings where one person dominated the meeting and no part of the agenda would be accomplished. If Cory was going to lead a STEM initiative at his school, he knew he needed to be careful about who he invited to the group to make sure it was successful.

Cory: Hey guys, glad I could catch you for a minute, would you be interested in joining the STEM team this year? Jared, I know you were on it last year, the university is funding us again this year. Angel, I thought of you for this year because of the innovative work you are doing in your class.

Jared: yeah of course, I really enjoyed being able to create some lessons with everyone last year.

Angel: Tell me more about what I would have to do.

Cory: Well, we get to decide our agenda. There is no set agenda for us, or hoops to jump through. It will be a time for us to get together and weave STEM into our teaching and have time to integrate cross-curricular themes in to our classes.

Angel: OK, is it taking the place of our required team meetings?

Cory: No, since we are always bogged down with other agenda items, and never get to talk about teaching in our classes, this would give us that time to focus on curriculum and teaching. I know you have a lot of great ideas, and I never get to hear about them or see them, and maybe we can find some commonalities and finally make those connections between our classes.

Angel: So, when would we have these meetings, there is no time during the day!

Cory: I realized that, and it's not ideal, but we would meet after school on Fridays. This is the only day I could think of because we all teach after-school programming Monday through Thursday. We do get paid for all of our time however.

Angel: Can I think about it?

Cory: Yes, and again, this space is not to increase any type of stress whatsoever, I know you have things with your daughter after school sometimes, and you can just come to the first meeting and feel it out. If it's not working, we can change it up.

Jamie was not a part of choosing the team members or the invitation conversations. She trusted that Cory's previous experience collaboratively working on team projects prepared him to pick people who would positively contribute to the STEM team. While Jamie personally hated the idea of meeting Friday after school, it also showed a level of commitment from the teachers to meet at the end of a busy week.

Cory had told Jamie that some of the members had no STEM experience, and so they would spend their first meetings talking about what STEM was. Jamie liked this idea, because even though she was used to working with teachers who did have STEM experience, she knew that the multiple and broad conceptions of STEM could actually hinder a team. By starting the year grounding what STEM meant to the team collectively, she felt it would set them up to be more successful. By the end of the week, each of the teachers Cory had approached joined the team. There was an excitement about the possibility of creating something interdisciplinary, a task that had not been accomplished the previous year with a multi-grade team.

October: Fitting into the School System

After getting his team together, Cory and Jamie needed formal permission from the principal for the proposed work. Jamie had reached out to him multiple times through email and he had not responded to her. She had also asked for him when she checked in at the office, but had not connected with him. She was happy for the opportunity to work with this school district and needed to make sure that all of the permission steps were followed. Two years prior, the district had discontinued most student research due to misrepresentation of data. Jamie asked Cory to collect the formal consent because of his proximity and relationship with the principal, Mr. O'Malley.

Cory walked into the office to talk to Mr. O'Malley about the consent form his team needed. Mr. O'Malley, whose attention was noticeably engaged in other projects, asked Cory to come into his office to talk.

Mr. O'Malley: So, first, I am excited to see that you are taking on a leadership role as a teacher around here. I was hoping you would do that this year so I am proud to see that this is a good avenue for you to take.

Cory: Thanks, yeah it has been hard to find time while teaching after school program and doing the robotics team to find any more time to take leadership roles, but this one means something different to me since I have complete autonomy over the project.

Mr. O'Malley: That is pretty cool, and is this connected to some of the work you have done before with curriculum writing and stuff?

Cory: Yeah, it's with my partnership with the university, it's pretty great to have these resources. You can never have enough of those, and to make strong connections to the university is a way to get people outside of our school involved with our students' education.

Mr. O'Malley: We have some projects already started here, but the projects need more assistance, and I just think that you and your team should take over these projects.

Cory: I want to be very upfront with you, I'd rather not have a STEM team if we are going to be assigned tasks. The whole point is for the team members to have autonomy and work together.

Mr. O'Malley: Well, I can't MAKE you work on either of these, but I thought I would try.

Cory felt tension in the room as he told his principal that he was going to be in charge of the team's agenda. Cory walked out and called Jamie to tell her he got the consent form signed. Jamie was relieved to hear this, she felt like she was pestering Cory by asking him multiple times to get it signed, but the STEM team could not officially start without it. Jamie kept going back to the conversation they had about what partnership was and she did not feel she was keeping up her end to support him, but there were some jobs that only he could do because of his positional as a teacher in the school. Jamie listened to Cory as he talked about his meeting with Mr. O'Malley. He sounded upset, but reiterated that the whole reason he was leading a STEM integration team was to get away from this exact conversation. He wanted his team to create something on their own that they believed in and could put the effort behind and Jamie assured him they would try.

December: Defining STEM

Jamie was early to the STEM team meeting. She purposefully sat at the end of the table as she wanted Cory to be placed in a position of leadership and lead the meetings. She pulled out her audio recorder and slid it to the middle to make sure everyone's voice was recorded. In this position, she could take notes but also be available when needed, but not be intrusive.

Cory: I know this seems funny because STEM seems like such a big thing that we hear about all of the time now, but there is really no one definition of STEM. We are going to look at a few different existing models and think about the one we want to use this year. Before we look at those, lets share what our definitions of STEM are at this point.

Angel (looking at Jamie): How do you think we should define STEM for our team?

Jamie: I think that you should all share your definitions and see if there is something in common. If there is you can work from that. If there is not, then it's a good place to start the conversation.

Angel: What if you don't like our definition.

Jamie: It is not up to me, it's your team and your definition.

Angel: Really? But what if we are wrong?

Jamie: There is no one "right" definition. Your definition needs to work with your teams' goals and how you believe STEM should look across your team.

While Jamie told the team that there was no right definition of STEM, she was aware that there were less useful definitions and if they missed the mark, she or Cory would have to address it. The team looked to her as an expert, and she was willing to help coach them through the formation of the definition, but would rather Cory be seen as the team lead to place decision-making within the teacher team and not coming from the university. Jamie wanted to build up the team's capacity of knowledge around STEM instead of having them rely on her. She knew she was not a permanent fixture at the school and if the team would be sustainable, they needed to take ownership of their STEM vision. The team went around the table and each shared their definition of STEM, including Cory. When the last person had shared it was noticeably silent so Jamie felt she could suggest a next step.

Jamie: It sounds like you do have some common ideas about what STEM is, do you agree?

The team nodded at Jamie and a few members verbalized agreement. They continued to look at Jamie.

Jamie: Ok, so let's start by writing down the common pieces and then work from there. Cory has also shown us different models of STEM, so if we have holes to fill, we can pull from those as well. Cory, can you get a shared document started and I will pass out the STEM models again.

Cory rose and put the images back up on the screen, this was a pivotal moment for the group. Cory felt each of his team members had overlap in their definition of STEM, but they need to come up with one solidified definition to agree upon. He knew that there was more research he could present to the team, but the meeting time always went by so fast that he did not feel they could go more in depth about what STEM. He also was wary to present models that existed outside of the constraints they were facing at their school because that could just lead to disappointment and put a negative spin on what they could accomplish. Cory knew this might lead to a simplified idea of STEM, but it also would lead to a practical and unified definition that would be useful in guiding the team forward.

January: The push to implement

Jamie was attending a bi-weekly research meeting at the university. All of the other STEM Fellows and the project leads regularly met to discuss what was happening at each school site. The research team had been together for two years, so it was common to use the meetings to support each other and be honest when they needed advice on a difficult situation. The meetings started by going around the table and having everyone share out new information form their school site.

Jamie: Well, we have had a few team meetings now. A lot of the members are new, so we spent some time establishing what STEM is, but we have not planned anything interdisciplinary yet. We don't really have a plan for that.

Fallon (graduate researcher): Have you made any suggestions?

Jamie: No, they asked me to bring in some curriculum materials, but it seemed like they wanted to use them separately in their classes, not try and create something together.

Janae (project lead): That makes sense, if they are new to STEM, they probably want to try something on their own to see how it goes.

Fallon: Do we have anything here at the university they could use?

Jamie: I was thinking about KIDwind, I have used it and would be able to support them with it.

Janae: I would bring it up to them, considering how difficult it is to develop integrated lessons from scratch, there is not much time left in the school year to get it done.

Jamie: I will email Cory right now and see what he thinks about it.

Jamie was unsure how Cory would respond to the idea. The teachers appeared to be working individually in their separate classrooms to integrate STEM and Jamie did not know if they would want to change their course. She also did not want to make them feel like she was assigning them KIDwind as a task to complete. This would go against the autonomy the team was given to create their own STEM integration unit.

Cory saw Jamie's email and decided to pitch the idea to the team. After missing more than a month and a half of meetings with holiday breaks, he also knew they needed to make progress towards their goal to implement an integrated STEM unit. Jamie had used the KIDwind curriculum before and she volunteered to lead the next meeting to introduce it to the team. Cory knew his team were tired, they were teaching full time, attending to other school initiatives, and then he was asking them to plan an entire STEM unit from scratch. Cory saw KIDwind as an opportunity to take some of the pressure off the team. He asked Jamie to present KIDwind as a starting point, one that they could pull from and modify it to meet the needs of their students.

February: Reflecting

Jamie met Cory and the STEM team at a restaurant for their monthly meeting. They had asked not to meet at school because they felt more comfortable being honest about their reflections when they were off site. Cory had shared that 25% of the school staff had been pink-slipped for the upcoming school year, including two teachers on the

STEM team. Jamie was thankful that Cory had shared this information with her because she knew that it would impact the teachers' feelings towards the school and the work of the team. After the STEM team had settled, Jamie asked each person how the KIDwind lessons were going.

Angel: We didn't get through as much of it as I was hoping, and I feel like I am falling behind!

Cory: Angel, don't worry! Remember implementing new things takes time, something we rarely get! We are still all teaching the unit at the same time.

Angel (visibly reassured): Thanks Cory, I don't know, I just always feel like I am pushing through curriculum to meet the school's agenda, and I guess I am stuck in that mode. But I have to remember that this is something different.

Cory: Remember, if this project causes any type of stress, back off a bit and then come back to it.

Angel: Alright, well maybe we will take a break from The Boy Who Harnessed the Wind for the rest of the week, and pick it back up on Tuesday next week. Some of my students are still finishing our big test and they will need Monday. I will say they are really enjoying it. One of them yelled yesterday "WE ARE DOING THIS IN MR. CORY'S CLASS!", It was so funny. It's like they have never felt what it is like to be learning things around the same theme throughout their classes.

Jean (looking at Jamie): Are you getting what you need from us, it feels like we aren't doing very much for you. You are in our rooms teaching and stuff, is that enough for the university?

Jamie: I am interested in the process of integrating STEM, and this is the real process. It's not easy and it's important to highlight all of the other "stuff" teachers have to do that gets in the way. You did something a lot of other schools didn't, you are implementing an integrated STEM unit, and it's important that other teachers who are interested in this work understand that you had real struggles too, that this wasn't a cake walk because it never is.

May: Publication

Jamie met with Cory at a coffee shop. She wanted to start writing a proposal for an upcoming research conference. Because of the focus on the school partnership, she knew she wanted Cory to be a co-author on the paper with her.

Cory: You know I have no idea how to do this, right?

Jamie: Yes, you do, you were there the whole year, who better to write about it?

Cory: But I have never done anything on the research side before.

Jamie had felt a personal tension throughout the year to sit back and let Cory lead the STEM team. She knew that Cory was the expert in his classroom and never wanted to challenge that. As a former teacher, she was always cautious about inserting herself into the classroom space because she knew, as a researcher, she was the outsider. Now as they were leaving the classroom space and beginning the analysis process, she felt the power structure changing. Cory was relying on her for guidance, he was now the outsider in the research space even though he was aware of the research being conducted.

Jamie: We want to better understand what made our partnership effective.

Cory: For clarification, why are we saying this partnership was effective?

Jamie: Good question. I think it was effective because our goal was to create and implement one interdisciplinary STEM unit, and we did that.

Cory: Ok. But I think there is more to it than that. I am still not sure what was different, but I think it is more than implementing our one project.

Jamie: How about this, let's individually start writing down moments throughout the year that we thought were important in our partnership. The pivotal moments. The moments that we would want to share with other people who are thinking about starting a STEM university-school partnership.

Discussion

Co-constructed narratives opened windows to the university-school partnership with the purpose of highlighting personal experiences, and represent the individual accounts of both the researcher and lead teacher. The narratives become avenues to discuss what makes partnerships successful given both the teacher and researcher's perspectives of the events that occurred. Reading through the narratives, two re-occurring themes arose, the role of the insider and outsider positionality and prioritizing the "school" in school-university partnerships.

Insider-Outsider Positionality

The first theme discussed is the role of the insider and outsider. Both roles were evident, however, they did not remain static. Although Jamie had previous teaching experience, she still was joining into the partnership as a researcher and did not have existing relationships at the school site she was working at except with Cory. By definition of Bartunek & Louis (1996) she was an outsider because she was the one conducting the research. As the year progressed, she developed relationships with faculty and began co-teaching which made her less of an outsider because her positionality was changing. In May, she again solidified her role as outsider when she meets with Cory to lead them towards publication as the researcher. Although Jamie is considered the outsider throughout the partnership, it is clear that the degree she is actually "outside" of the school and teaching space vastly changes.

One reason for the separation between insider and outsider is due to differences in their purpose for gaining knowledge (Bartunek & Louis, 1996). Jamie acknowledges that supporting the researcher's agenda is a common theme with the relationship between researchers and teachers, but that her "main goal was to make sure this doesn't happen." Cory then expresses that he was worried about participating in the STEM development program because doing "more work, just to benefit someone else is a bit discouraging", but Jamie reassures him that this will not be the case and that his STEM team's goal will be equally prioritized. Acknowledging and enacting of both the insider and outsider's goals is key to partnership (Bartunek & Louis, 1996).

While the study relied on Bartunek and Louis's theory (1996), it also challenges parts of their definition of insider and outsider. Bartunek and Louis's description of the outsider is the one who is conducting the study and the insider is the one being studied. In our study, after the STEM team set their goal, they were equally as active as Jamie in conducting the study and Cory, as the team lead, was also active in writing and presenting the research findings. Cory and Jamie did not seem to fit the binary of either teacher or researcher as they both moved into each other's spaces throughout the study.

The continuous movement along the continuum of insider and outsider seen in this study supports Bartunek and Louis's notion (2016) of fluidity, but we argue that at times the roles may have changed because of the actions that Cory and Jamie were taking. At the beginning of the partnership they had set roles, but as the narratives progress, there are times Cory was directing the research and Jamie was in the classroom teaching. As the partnership goes on, the blurrier the line between roles becomes until the end when Jamie clearly takes the lead as researcher again. As the narratives were analyzed, Jamie and Cory both confirmed and contrasted Bartunek and Louis's theory on insider-outsider research teams.

Prioritizing the "School" in School-University Partnerships

MacLean & Mohr (1999) state that in partnerships, the researcher is viewed as having more power. Cory contrasts this when he agrees to be a part of the STEM development program because his team was able to set their own STEM related goal. He made sure that if they participated, they would not "be meeting someone else's agenda". In the initial meeting in August Jamie and Cory agree that it is the STEM team who will be setting the goals and that Jamie will be there in a supporting role. Throughout the narratives, Jamie was conscious of her approach and her positionality so that she respected the partnership between the university that she was representing and the teachers she was supporting.

During the off-site meeting, Jean asks Jamie if she is getting the research she needs. Jean was relatively unaware of Jamie's research presence, an indication that Jamie's work was not interfering with the teams' research. This was purposeful as Jamie was working against the models of partnership such as Maurrasse's (2001) landlord example where the university is a ruling figure that would place their research agenda first and overshadow the goals of the teachers. Instead, the teacher's work was prioritized in this partnership. Due to the way that Cory and Jamie set up the partnership, the STEM team was able to use their shared time on meeting their own goals.

Implications for Teachers and Researchers

In the past teachers have played a non-existent or passive role in how their students and their teaching practices are portrayed in research (MacLean & Mohr,1999). However, new research methods (Sagor, 1992; Cochran-Smith & Lytle, 1993) are valuing the collaborative nature of teachers working in partnership with researchers. Teachers and researchers looking to engage in a school-university partnership should be selective in choosing their partners which align to their goals (Bartunek & Louis, 1996). Before entering into a partnership, teachers can ask for support from the university to accomplish their own goals. If the university cannot support the teacher's in their work, then the partnership will not be successful. "The greater the difference between the insider (teacher) and outsider (researcher) the greater the challenge the two parties face building a working relationship (Bartunek & Louis, 1996, pg. 28). Similarly, it is important for researchers to develop relationships with those that are being researched by solidifying their role as advocate for the teachers. When the researcher is honest and provides clarity about the University's agenda, mutual growth and respect can develop among all participants (Tikunoff & Ward, 1983).

Another way to establish a relationship is to choose a methodology that focuses on co-construction of knowledge instead of a single entity controlling the process. Cory did not have to initiate this because Jamie had entered into the partnership intending to include Cory in the publication process. Because teachers and researchers see the partnership from different perspectives, joining their accounts together solidifies the accuracy of the actual accounts. The ideal publication outcome is one that goes beyond both the insiders' and outsiders' original viewpoints, such as a new way of understanding" (Bartunek & Louis, 1996, pg. 50). If teachers are not offered to participate in the writing process, they should be able to advocate to be included in this as it is a part of the partnership as well. This may include reading and revising the manuscript, co-writing, or being given authorship on work they approve. Each of these acts can be seen as a push towards closing the gap between insiders and outsiders that will also lead to the production of higher quality research publications.

Conclusion

In this study, the teacher and researcher who participated in a school-university partnership shared their experiences as they collaboratively worked toward moving STEM from a theory into practice. In order for both participants to share their simultaneous experiences, data was collected and compiled into co-constructed vignettes. Both the writing process and the analysis of the vignettes led us to our discussion and implications for teachers and researchers. This study is one portrayal of how a successful school-university partnership was formed.

Chapter 4: What do Elementary Teachers Need to Integrate STEM?

Praxis between STEM education policy reforms and classroom instruction in elementary school remains large. The U.S. government designates $3 billion every year to increase science, technology, engineering, and mathematics (STEM) education initiatives (Pittinsky & Diamante, 2015), more than half of that money is dedicated to post-secondary education efforts. That leaves a considerably smaller amount of money dedicated to K-12 STEM education. The least amount of STEM programming is in elementary school (Committee on Education the Workforce, Subcommittee on Early Childhood, Elementary, Secondary Education, 2013). “Much attention has been focused on STEM (science, technology, engineering, and mathematics) education for high school and, more recently, for middle school students. However, to have the greatest impact on students and STEM learning, we believe that the emphasis needs to begin at the elementary level” (Committee on Education the Workforce. Subcommittee on Early Childhood, Elementary, Secondary Education, 2013).

Although elementary grade levels are often not the focus of STEM initiatives, it is a critical time for students in identity and interest development in STEM. Elementary school is influential on student’s STEM identity (Kroger, Martinussen, and Marcia, Lindall 2007) and a recent study found that students whose science interest began by age eight were far more likely than others to persist in their STEM career interests during secondary school (Aschbacher, Ing, & Tsai, 2014). In a report published by Congress entitled *Raising the Bar: Reviewing STEM Education in America* (2013), the committee pointed out that “if you don’t get [students] interested in [STEM] in the elementary school, they are not going to have any interest in high school” (p. 27).

However, elementary teachers are the least prepared to teach STEM. Elementary teachers often do not feel prepared or comfortable in teaching science and mathematics and instead of engaging students in STEM pedagogy, relying on textbooks and traditional approaches to teaching science and mathematics (Goodnough, Pelch, & Stordy, 2014). At times teachers may ignore science entirely because it receives very little attention in the overall school curriculum anyway (Davis, Petish, & Smithey 2006; Holroyd & Harlen 1996; Murphy 2012; Murphy, Neil, & Beggs 2007; Trumper 2006; ZembalSaul, Blumenfeld, & Krajcik 2000).

This study enacted an explanatory research design, as it was not intended to offer final and conclusive solutions to existing problems, but to draw together existing literature and new data to lay a foundation for those interested in STEM integration in elementary schools. The purpose of this study was to ask teachers working in elementary schools that have sustained STEM programming what factors they believed were important to STEM integration. The research question this study aimed to answer was:

> What factors do elementary teachers currently working in schools with STEM programming cite as being important for STEM integration to occur?

STEM Education

STEM education has been cited as important because of its ability to prepare students for both STEM and non-STEM related jobs (NRC, 2011, 2013). The National Science and Technology Council (2013) explained that the jobs of the future are STEM jobs and even jobs that are not in STEM fields will need the critical thinking and problem-solving skills that STEM education provides. Today, there is a clear consensus among stakeholders on the importance of STEM education to economic innovation (Kuenzi, 2008; OECD, 2010). The United States Secretary of Education stated that “it’s important that all students have access to a high-quality STEM education. These discretionary grant programs and this Administration’s increased focus on STEM will help ensure our nation’s students are exposed to STEM early in their lifelong education journeys and have the tools needed for success in the 21st century economy” (STEM Education, 2018).

When STEM appeared in the National Science Foundation (NSF), NSF had used STEM simply to refer to the four separate and distinct fields we know as science, technology, engineering, and/or mathematics (Sanders, 2009). In 2009, integrative STEM was defined as “approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects” (Sanders, 2009, p. 21). It is both the content knowledge from the individual science, technology, engineering, and mathematics fields, as well as the interdisciplinary approach that has made STEM education a valuable part of K-12 education (Zollman, 2012).

As more government funding is designated to fund STEM education, it is important to establish a definition of what STEM education is. Unfortunately, the term STEM has been ill-defined (Sanders, 2009). There are many models of STEM (Bybee, 2013) and no one model has been agreed upon as the “correct” model.

Bybee has developed 9 models of STEM integration that fall along a continuum of integration (Bybee, 2013). Figure 4.2 and Figure 4.3 represent two of Bybee's models that visually show two different approaches to STEM education.

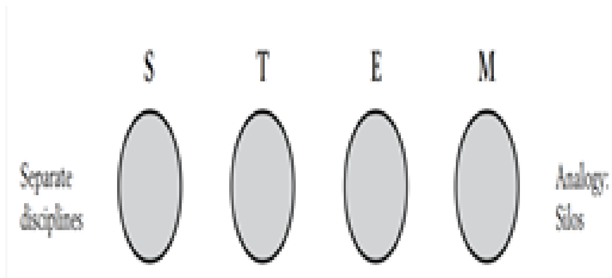

Figure 4.2. Bybee's STEM model of Separate Disciplines. Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. National Science Teachers Association.

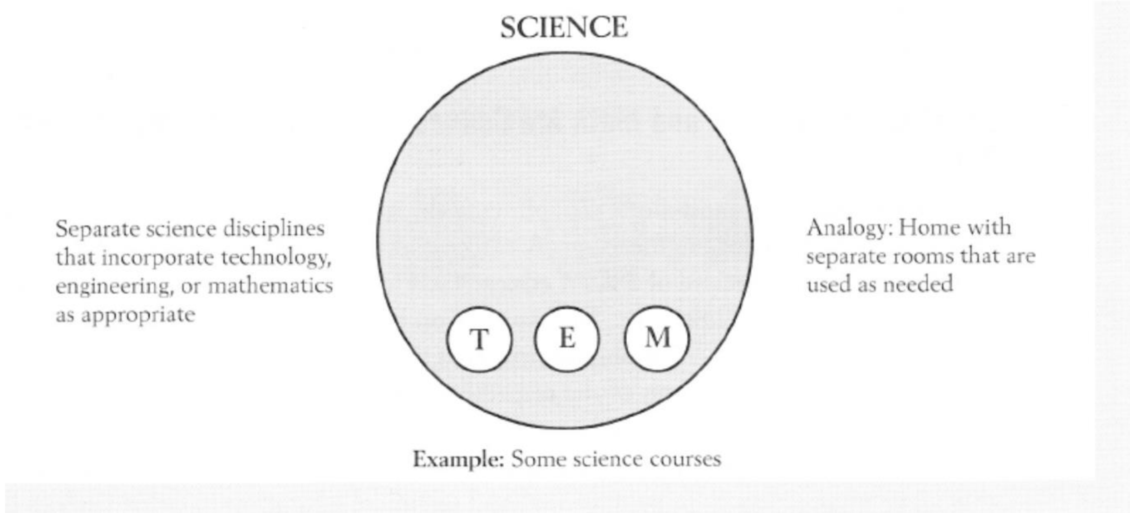

Figure 4.3. Bybee's Model of STEM Separate Science Discipline that Incorporates other Disciplines. Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. National Science Teachers Association.

In figure 4.2, all four content areas are separate from each other, and learning occurs in siloed spaces. Each content area receives the same amount of time and focus. In the figure 4.3, science is the content area that is the focus of learning and technology, engineering, and mathematics play supporting roles in the science lesson. The overlapping circles represent that all four content areas are being taught at the same time Bybee does not rank one model as better than another, he just acknowledges that they both currently exist in STEM education. Bybee's models contains all four content areas, but some researchers question if all four content areas need to be present to be considered a STEM lesson. As funding for STEM education continues, it is important to better understand STEM integration at all levels, including elementary grades.

Elementary teachers and STEM

Teachers play a critical role in exposing and encouraging students in STEM fields (National Science Board, 2007) but elementary teachers are typically generalists and have not completed majors, or even minors in STEM disciplines (Goodnough, Pelch, & Stordy, 2014). Elementary teachers also must combat a prioritization on math and reading, content areas that are evaluated on standardized tests (Rivera Maulucci, 2010). Standardization is one cause of less time devoted to science in elementary school, but inadequate resources (Banilower et al., 2013), elementary teachers' anxiety and negative attitudes about teaching science (Tilgner, 1990), and deficits in elementary teacher preparation (Fulp, 2002) also contribute to a lack of science instruction in elementary grades. Only 30% of elementary education programs at the undergraduate level require pre-service teachers to take a science course and 44% of graduate-level elementary teacher education programs do not require candidates to take a science course (Greenberg et al., 2013). Only 1% of elementary teachers had any college coursework in engineering (Horizon, 2013, p. 12). To add on, pre-service elementary teachers have some of the highest rates of math anxiety while coupled with below average math proficiency (Novak & Tassell, 2017). The culmination of these factors depict an image of elementary teachers who are unprepared to teach STEM.

It is important that teachers are asked what factors they believe are important to STEM integration. By directly asking teachers who have been through the process of STEM integration at their school site what factors they believe are important clearer picture of the teacher's prioritization of factors related to STEM implementation can be identified and addressed.

STEM School Critical Components

In 2014, Peters-Burton, Lynch, Bebrend, and Means developed ten critical components that they identified as foundational to inclusive STEM high schools. The critical components were developed after doing cross case-analysis of exemplar Inclusive STEM high schools. When looking across school cases, researchers were searching for “positive deviants” (Peters-Burton et al., 2014) or factors that seemed responsible for the success of the STEM schools. These positive deviants were then renamed critical components and published as a framework for developing inclusive STEM high schools.

However, criteria specific to STEM high schools may not all be relevant to an elementary STEM school. For example, critical component 6 titled college level coursework is defined as “flexible scheduling that, providing opportunities for students to take classes at college or online”, seems unrealistic to be named as a critical component of an elementary STEM school. For this reason, in 2017, the Elementary STEM (ESTEM) critical components were introduced (Peters-Burton, 2017). Researchers took the same approach as before by identifying an inclusive STEM elementary school that was exemplary and identifying the factors that set it apart. Twenty-four ESTEM critical components were identified (see Table 4.1).

Table 4.1

ESTEM Critical Components (Peters-Burton, 2017).

Student Learning Experiences

- *Teaching and learning emphasize inquiry or design thinking*
- *STEM is integrated throughout school curricula*
- *Teachers facilitate student interest in STEM*
- *School programs are coherent and supportive of STEM*
- *Students experience autonomy in learning*
- *Out-of-school programs and resources provide STEM-rich experiences*
- *School schedule offers a large amount of science learning opportunities*
- *Instructional approaches include project-based learning, personalization, and other reform strategies*
- *Students participate in service learning or other community activities*

School Staff

- *School leadership is inclusive and focused on instruction*
- *Teachers are open to innovation and continual learning*
- *Teachers are supported in STEM through collaboration, training, and resources*
- *School administration is flexible and autonomous*

Families and Community

- *External partners deepen the school's STEM capacity*
- *School establishes and maintains relationships with community*
- *School population demographics represent district or local community*
- *Families are included in classrooms and the school*

Technology

- *Technology is integrated into activities of both students and teachers*
- *Students learn and use workplace and life skills*

Data-driven Decision Making

- *Dynamic assessment systems inform instruction*
- *Staff use evidence in continuous improvement process of school model or programs*

School Culture

- *School builds awareness and emphasizes the importance of future plans and pursuits*
- *Program designs include sustainability, scale, spread and flexibility*
- *Trust and respect are shared among staff and students*

The critical components were meant to bring attention to inclusive STEM schools. In the past, STEM schools were usually selective, serving students identified as gifted, and denying students who may need additional support (Peters-Burton et al., 2014). However, the "current trend is inclusive STEM schools, schools that focus on rigorous

STEM education for any student who wants to attend regardless of prior academic achievement" (Peters-Burton et al., 2014, p. 65).

Study Design

This study was enacted through Exploratory Research Design (Salkind, 2010). This methodology was chosen as the purpose of the study was to explore the research question and does not intend to offer final and conclusive solutions to existing problems. Little research surrounding what factors elementary teachers report as being important to STEM integration has been done. This exploratory study can be a foundation, or starting point, for those interested in STEM integration in the elementary grades.

Participants

The National Center for Educational Statistics (2018) publishes a list of inclusive elementary schools. Like Peters-Burton definition, schools that are included on this list accept all students. For each school in Minnesota, their school website was visited and schools were included if there was explicit mention of STEM programming: a STEM specialist, a makerspace, or if the word "STEM" was mentioned on the homepage of the school's website. Makerspace was included because the "maker movement" has sparked interest for its potential role in breaking down barriers to learning and attainment in STEM (Peppler & Bender, 2013). From the original list of 260 schools, 42 schools (Appendix 1) were identified as having at least one feature of STEM programming at the school. An email was sent out to all K-5 classroom teachers requesting that they complete the survey (Appendix XXX). Teachers include classroom teachers, special education, intervention, gifted and talented, as well as specialists. In total, 996 teachers were invited to complete the survey, 196 teachers completed the survey (20% response rate).

Methods

Data Sources and Data Collection Process

A Qualtrics survey was developed asking about the factors that the teacher believes have led to STEM implementation and/or sustainability in their public elementary school using a 6-point Likert scale. A rating of 6 correlated to extremely important and a rating of one correlated to not important at all. The questions were modified based on the ESTEM report (Peters-Burton, 2017) that suggests 24 critical components that successful elementary STEM schools share in common (see Table 4.1). The categories include student learning experiences, school staff, families and community and school culture. Participants were asked to then to identify the three components that they believed were most important for STEM integration at their school. Teachers were also given the option to answer an open-ended response question if they wanted to provide more information or input about STEM at their school site.

Data Analysis Approach and Process

The first round of data analysis used was descriptive statistics (Hays, 1973). After the surveys were collected, graphs were made of the data and the basic features of the survey data was described. The questions were grouped into the category's student learning experiences, school staff, families and community and school culture. Next, inferential statistics (Hays, 1973) were used to infer what factors are most influential in STEM integration in elementary school.

Findings

Overview of Schools with STEM Programming

Overall, 96% of teachers who responded to the survey reported some level of STEM at their school site (Table 4.2). The majority (64%) reported that STEM was the learning focus for the entire school. Four percent of respondents replied that they did not offer STEM learning opportunities at their school site. The data of the participants who reported no STEM programming were not included in the subsequent data analysis or results.

Table 4.2

STEM Programming

Question	% of Responses
Yes, STEM learning is the focus of the entire school	64
Yes, STEM is happening in at least one classroom	32
No, we do not offer our students STEM learning opportunities	4

When asked what STEM-related resources were available at their school related to STEM programming, the answers varied (Table 4.3). The resource that was most prevalent was a technology specialist (64%). The least prevalent resource was a science specialist (24%). Eighty-four percent of teachers reported having two or more resources at their school (Table 4.4). The most common combination that schools had was a STEM specialist and a technology specialist followed by a STEM specialist and an outdoor learning space.

Table 4.3

Resources that teachers reported schools having

STEM Resource	% of Schools that reported having this resource
STEM Specialist	56
Science Specialist	24
Makerspace	53
Outdoor Learning Space	57
Math Specialist	26
Technology Specialist	64

Table 4.4

Number of STEM resources at each school reported by teachers

Number of STEM Resources	% of teachers reporting they had this number of resources at their school
0 STEM Resources	4
1 STEM Resource	12
2 STEM Resources	23
3 STEM Resources	38
4 STEM Resources	17
5 STEM Resources	4
6 STEM Resources	2

Factors that are important to STEM programming integration

The average response from the teachers for the importance of each critical component for STEM is reported in Table 4.5.

Table 4.5

Critical Component Survey Results

Question	Average Teacher Response (out of 6)
Perceptions of the importance of student learning experiences	
• Teaching and learning that emphasize design inquiry	4.514
• Teaching and learning that emphasize design thinking	4.183
• STEM is integrated throughout school curricula	3.796
• Teachers facilitate student interest in STEM	4.077
• School schedule offers a large amount of STEM learning opportunities	3.711
• Instructional approaches include project-based learning	4.021
• Technology is integrated into the activities of students	4.014
Average	4.045
Perceptions of the importance of school staff	
• The STEM program is sustainable, it is not teacher or administrator specific	4.184
• Teachers are supported in STEM through training	4.282
• Teachers are supported in STEM through material resources	4.267
• School leadership is focused on STEM instruction	3.759
Average	4.123
Perceptions of the importance of school culture	
• Teachers are open to innovation	4.454
• Teachers are supported in STEM through collaboration	4.366
• Teachers are open to continual learning	4.475
Average	4.431
Perceptions of the importance of community	
• Students participation in service learning or other community activities during the school day is important to STEM integration	3.471
• School establishes and maintains relationships with community STEM partners	3.794
Average	3.633

Perceptions of the importance of student learning

Two areas that were reported lowest in this category were that “STEM is integrated throughout the school’s curriculum (3.796) and “school schedule offers a large amount of STEM learning opportunities (3.711). Table 4.3 showed that 56% of teachers reported having a STEM specialist and 84% of teachers reported having two or more STEM resources (Table 4.4). The reporting brings up the possibility of STEM being a single disciplinary class compared to a multidisciplinary model. If teachers are reporting that scheduling is less important to STEM integration, it also could mean STEM as occurring in a single space, not across disciplines as interdisciplinary work requires a significant amount of scheduling flexibility. One teacher optionally wrote in the survey they felt “a big thing that is happening lately is that STEAM is becoming a pull out/extra class instead of an integrated way of learning. This is sad and hard as a teacher who loves that art and philosophy of STEAM and what it can be for learners”. This teacher’s comment supports the idea that STEM may be in select spaces in elementary school because of STEM specialists and/or pull out STEM experiences.

Perceptions of the importance of school staff

Teachers reported each of the components in this group similarly, except the component school leadership is focused on STEM instruction. This was ranked lower (3.759) than the rest. However, teachers reported that training and resources were important. This brings up whether STEM is growing from a top-down perspective where the administration is leading the STEM initiative or if STEM is being implemented from the bottom-up being grown by teachers. Teachers may be reliant on school leadership for the time and materials to integrate STEM, but do not believe that the administration must have a focus on STEM themselves.

Teachers strongly believe that materials are important to STEM integration. This is an interesting area to unpack to find out more about teachers' ideologies about boxed STEM curriculum compared to STEM pedagogy. A teacher acknowledged that they did not have any STEM programming until a booster foundation provided the school with "STEM Hubs". This resource was what sparked interest in STEM in the school. Knowing that elementary teachers are the least prepared to teach STEM, introducing physical materials, such as a STEM kit, as starting point is an interesting topic of research.

Perceptions of the importance of school culture

This group had the highest overall ranking compared to the other groups in the ESTEM survey. The ability to think innovatively as well as seeing the importance of continual learning are traits that have been associated with STEM teachers (El Nagdi, Leammukda, & Roehrig, 2018). Being open to continual learning is especially important because it is likely that elementary teachers who are currently practicing did not receive STEM training in their teacher preparation courses (Nadelson, Callahan, Pyke, Hay, Dance, & Pfiester, 2013) and therefore need to be open to learning more about STEM pedagogy in order to implement it.

This group also contains that teachers need to be supported in collaboration to integrate STEM. Collaboration by definition insists that STEM is not happening in one classroom or by one teacher, but that working together is an essential part of teaching STEM.

Perceptions of the importance of community

This group of items had the lowest overall ranking compared to the other groups in the ESTEM survey. After reviewing the 42 participating schools from their district websites, it was found that more than half of them had received external funding for STEM programming from a partner organization. However, research has shown that giving teachers curriculum without accompanying professional development does not yield productive results (Darling-Hammond & McLaughlin, 1995). Based on the survey results, STEM implementation may rely more on the teachers' ability to integrate than securing the materials and resources for STEM.

Service learning was also in this section of the survey and received the lowest score on out of all of the components. Service learning is not traditionally thought of as a STEM component (Peters-Burton, 2017), so the relatively low ranking is not surprising in the survey results.

Discussion

As this was an exploratory study, the purpose was to find what teachers thought about STEM in their schools and use the report to then consider implications. It is crucial in planning to use teachers' input. One of the things that educational practitioners need to think about is the teacher's needs, and "the only way for people to find out is to ask teachers" (Park, Rogers, Abell, Lannin, Wang, Musikul, Barker, & Dingman, 2007, p.10). After looking across the survey results and the teachers' comments, this study identified the highest rated factors reported with the highest importance and posed further possibilities going forward keeping the teachers' reports primary.

Inquiry Based Learning

Design inquiry was the highest ranked in the survey by teachers. This may be ranked high because, although a buzzword in scientific education, elementary teachers have had limited exposure and experience with inquiry (Lee, Hart, Cuevas, and Enders, 2004), but understand it to be important to STEM integration. Teachers often revert back to how they were taught (Nadelson et al., 2013). Inquiry is connected to the adoption of the NGSS in 2013 so it is likely they will not have experienced inquiry as learners themselves. Because of its complexity, inquiry can be hard to implement (Settlage, 2007). Unlike traditional science instruction that had been teacher directed, inquiry “allows students to conduct investigations to test questions about the natural world and then use the evidence they collect during their investigations to articulate an explanation in terms of scientific concepts and principle (Grigg, Kelly, Gamoran, & Borman, 2013). An instructional shift will require learning and guidance for teachers, such as in-depth, long term professional development (Grigg et al, 2013). Professional development can take many forms, including mentoring, coaching, and lesson study, but the standard approach in the United States remains training in the form of in-service workshops, on which billions of dollars are spent annually (Birman, Le Floch, Klekotka, Ludwig, Taylor, Walters, & Yoon, 2007). The survey was not explicit on what approach to professional development teachers would prefer, so more investigation is needed in this area.

Utilizing Material Resources

In-service elementary teachers will need professional development to create positive STEM identities, but they will also need to see STEM learning modeled, and we used the survey to imagine what that might look like. Teachers ranked material support very high as well, and as more pre-made STEM curriculum is available, it makes sense that teachers may connect STEM to kits. Because elementary teachers do not have a foundation of STEM, exposing them to existing STEM lessons or materials to engage teachers may lead to greater engagement than asking them to start by creating their own STEM lessons with no prior experience or background knowledge. For example, elementary pre-service teachers who took part in a robotics professional development reported their STEM engagement improved overall as well as their emotional engagement (e.g., interest, enjoyment) in STEM significantly improved (Kim, Kim, Yuan, Hill, Doshi, & Thai, 2015). In a second study, researchers again found that professional development led to an increase in teachers 'self-efficacy and interest in teaching STEM, but they explicitly attributed the changes [in teachers' self-efficacy] to the methods of delivery, BrickLAB, which "supported the development of deeper understanding of understanding of STEM by engaging in hands-on, inquiry-based activities"(Nadelson et al., 2013). Goodnough, Pelech, & Stordy (2014) worked with elementary teachers who had no prior STEM experience. They asked teachers what they wanted from their professional development experience and 95% of the teachers wanted the opportunity to participate in hands-on activities and try out practical activities that would meet curriculum requirements. In all cases, the use of an existing STEM material contributed to teacher learning. STEM materials were highly rated on the STEM survey in this study. A future research interest could be using existing STEM kits as a gateway for elementary teachers into STEM because they have been shown to be engaging and positively correlated to elementary teachers' self-efficacy in teaching STEM.

Administrative Support

Although administration is never called by name, the school culture, which was rated highest, is a direct reflection of the administration. In *The Principal's Role in Successful Schools* (2008), Shelly Habegger explains a positive school culture is one in which the principal's decisions are guided by the teachers wants and needs. However, the administrative positions still hold final decision-making powers. If teachers are asking for continual learning (professional development), material resources, and time for collaboration as seen in the survey results, it ultimately comes down to the administration supporting these components of STEM integration or not. In a cross-case analysis of developing STEM schools, instructional leadership was identified as a key element of successful STEM integration (Crotty, 2018). When the administration is also willing to take on the role of leadership in STEM integration, teachers are better supported in their mission of integration as well.

The decision to integrate STEM throughout the entire school or create the role of a STEM specialist also is an administrative choice. From the survey, it appears that STEM in elementary school is often integrated through a STEM specialist, however, as the teacher reported that may not be the way teachers want it to be integrated. The teacher's ability to integrate STEM, either in their own classrooms or as a specialist, ultimately comes down to the administration's prioritization of STEM integration and their allocation of resources.

Conclusion

Drawing upon existing literature and survey data, this exploratory study begins to develop starting points for those interested in STEM integration in elementary school. Using the reports of teachers who are already working in schools with STEM integration has guided this study, as teachers' input is crucial to future planning surrounding STEM integration in elementary schools. Moving forward, this study suggests future research around inquiry-based learning and STEM, the role existing STEM material resources can have in teacher's acquisition of STEM knowledge, and the role of a supportive STEM administration. The original ESTEM report contained 23 components, a daunting amount of work to undertake for elementary teachers who are already not well prepared to integrate STEM. Using teacher reports, this study suggests three areas of focus for those beginning STEM integration in elementary grades.

Chapter 5: Moving Forward

National initiatives supporting the integration of STEM into schools have increased educational practitioners' interest in interdisciplinary learning across science, technology, engineering, and mathematics. But STEM integration is not going to come without challenges. With an elementary system focused on mathematics and reading and secondary education siloed into individual content and reliant on standardized curriculum, STEM integration needs some reworking of the American public-school system (Honey, Pearson, and Schweingruber 2014). While an entire overhaul of the systematic workings of public schools in America is not probable, at least not in the near future, there are still overlapping recommendations across these three papers that can be made to integrate STEM into the school system as they exist now.

Recruiting and developing STEM teachers

STEM education is not going to move from theory to practice implemented in K-12 schools without teachers who believe that the pedagogy surrounding STEM is best for their students. The three papers in this dissertation were all possible because the participating teachers all had an existing belief that STEM education was a worthy undertaking because it benefited student learning. The underlying belief that inspires those to pursue a new endeavor or persist in an existing one has past been called a person's ability to "buy into". Sinek (2011) sums this belief up as someone's "why". *Start with WHY* (Sinek, 2011) delves into the emotional and biological research that shows that those who begin with “why” are more successful than those who are not in any endeavor. Teachers must have their own “why” for choosing STEM. At a time when teachers are overwhelmed by a plethora of competing agendas (Skaalvik, M. & Skaalvik, S., 2017) this is no easy task, but schools and universities can align to make it possible.

Exposure to STEM can begin in teacher preparation programs. Teachers cite that their pre-service teaching programs influence their perceived ability to teach science (Bhattacharyya, Volk, & Lumpe, 2009) and technology (Blackley & Walker, 2017). so one could argue that the same results could occur with STEM. This is especially true for elementary teachers (Bowers & Ernst, 2018). For STEM to move from theory to practice we cannot only focus on pre-service teachers, in-service teachers must be considered as well. In-service teachers are unlikely to have had STEM in their teacher preparation (Bowers & Ernst, 2018). In order to develop STEM interest in teachers they must have exposure to high quality STEM instruction as well as be provided the time and environment to reflect on the STEM instruction they are experiencing (Bowers & Ernst). This task can be achieved through professional development. Most teachers prefer a setting where they practice student-learning themselves, reflect on tasks with peers, and interact with a facilitator (Posnanski, 2002). School-university partnerships can be the ideal solution. In both chapters 2 and 3, university faculty worked alongside in service-teachers as they participated in a yearlong professional development. University faculty members are both skilled in adult education and STEM content that qualifies them to facilitate STEM professional development for teachers. PD should be job-embedded and allow teachers to bring new innovations directly into their classrooms for practice, experimentation, and modifications (Zepeda, 2015). This suggests that PD should take place at the school and that teachers lived realities should be integrated in the PD as well (Kim & Ellingson, 2019).

Chapter four gave insight to what STEM needs school- university professional development can be created around. These included inquiry based learning, curriculum, and administrative level STEM reform. Elementary teachers cited these as the most important factor to move STEM forward at their school sites, but the same needs were presented by the middle and high school teachers as well. Curriculum and material resources were prevalent in all three papers. While the material heavy of STEM creates engaging and hands on learning, it also creates a problem as material costs are often not covered by the schools. Teachers need to rely on other means, which research Universities can often provide through public and private grant funding. In the partnership models depicted in chapters 3 and 4, both the teachers' and the researchers' needs had to be met for it to be considered a true partnership. To move STEM forward, it will require the university to assist teachers in developing curriculum and ensuring they have the supplies to implement it.

Viewing Students' STEM learning as a process, not a product

Most arguments for STEM in national reports (e.g., Carnegie Corporation 2009; National Research Council 2012) use common language as they call for increased attention to STEM education because it will prepare students for a future STEM workforce (Honey, Pearson, & Schweingruber, 2014; Vilorio, 2014). This model is eerily reflective of social efficiency ideology which society's needs, not the child, are the focus of schooling (Kliebar, 2004). It ignores the individuality of children as well as other aspects of learning, such as social and emotional development. It also devalues the institution of schools to a simple factory producing identical products. This model is in direct opposition to what is known about best practices in education that value whole child learning and differentiation. It also fails to acknowledge that learning occurs regularly. Allowing students to believe K-12 education is only applicable after students leave it and enter the workforce is providing them missed opportunities to see their growth in day to day settings.

Looking across the three papers, there is room to imagine that STEM education can be much more than the original reports led to. In chapter 2, STEM education offered students an opportunity to leave standardized learning and enter into something more engaging. At a time when standardized learning is moving towards uniformity, STEM allows for creativity and unique solutions (Cave, 2017). In chapter 3, the teacher-researcher team looked at STEM as an opportunity to make learning connect to the real world and take up the issue of renewable energy. They saw STEM as a way to presenting integration as a way to solve real world problems. (Breiner, Harkness, Johnson, & Koehler, 2012; Brown, Brown, Reardon, and Merrill, 2011; English, 2016). In chapter 4, teachers acknowledge that the inquiry approach is valuable. STEM education is moving away from rote memorization to students constructing their own knowledge. In fact, as STEM education is being integrated into teachers' practice, it is emphasising student-centered pedagogies (Breiner, Harkness, Johnson, & Koehler, 2012; Labov, Reid &

Yamamoto, 2010; Sander, 2009). Instead of focusing on future societal needs, I believe that all three papers show how STEM can transform our education system now.

Parting Thoughts

I entered into higher education to better understand why STEM education was not being put into practice in K-12 spaces with the same vigor that it was being talked about in academia and publications. My dissertation has given me a space to explore the barriers teachers interested in STEM are facing as well as the ability to pose pragmatic solutions. I believe that the adoption of the NGSS will only strengthen the commitment to STEM education moving forward and it is valuable to understand how we can find praxis between the research and implementation. Many teachers, like myself, did not experience STEM during teacher preparation programs, and therefore do not know how to navigate STEM integration when faced with daily realities of teaching such as standardized curriculum, siloed classrooms, and an emphasis on tested subjects like math and reading. My recommendation is that this dissertation can be a tool for other teachers and educational practitioners who are also trying to move STEM from theory into practice.

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Appendix 1

Participating Elementary STEM Schools

AFTON-LAKELAND ELEMENTARY

ANDERSEN ELEMENTARY

BATTLE CREEK ELEMENTARY SCHOOL

BURROUGHS ELEMENTARY

CARVER ELEMENTARY

CLEAR SPRINGS ELEMENTARY

COWERN ELEMENTARY

DEEPHAVEN ELEMENTARY

EAGLE LAKE ELEMENTARY

EAGLE POINT ELEMENTARY

EISENHOWER ELEMENTARY

EXCELSIOR ELEMENTARY

FIVE HAWKS EL.

GLEASON LAKE ELEMENTARY

GOODVIEW ELEMENTARY

GRAINWOOD EL.

GROVELAND ELEMENTARY

ISANTI INTERMEDIATE SCHOOL

ISLAND LAKE ELEMENTARY

JEFFERS POND ELEMENTARY

KENNEDY ELEMENTARY

LAKE ELMO ELEMENTARY

LAKEVIEW ELEMENTARY

MCKINLEY ELEMENTARY

MINNEWASHTA ELEMENTARY

MONROE ELEMENTARY

NORTH ELEMENTARY

NORTHWINDS ELEMENTARY

OAKWOOD ELEMENTARY

OTTER LAKE ELEMENTARY

PINEWOOD EL.

REDTAIL RIDGE ELEMENTARY SCHOOL

SCENIC HEIGHTS ELEMENTARY

SKYVIEW COMMUNITY ELEMENTARY

SOUTH ELEMENTARY CENTER

ST. MICHAEL ELEMENTARY

SUNNYSIDE ELEMENTARY

SUNRISE RIVER ELEMENTARY

VOYAGER ELEMENTARY

WASHINGTON ELEMENTARY

WILDWOOD ELEMENTARY

WOODLAND ELEMENTARY SCHOOL